VI. VOLCANIC ERUPTION

A. VOLCANIC ERUPTION OVERVIEW

B. DESCRIPTION

There may be no natural event that can cause greater damage to its surrounding area than the eruption of a volcano. However, eruptions can be mild, almost passive events that have little effect outside their immediate surroundings. The range of destructive capability is a function of the type of volcanic activity. Montana is bordered on two sides by areas of volcanic activity. To the west are the volcanoes of the Cascade Range (Mt. St. Helens, Mt. Rainier, Mt. Hood, etc.), and to the south is the Yellowstone Caldera.

The degree of destructiveness of a volcanic eruption is dependent on many factors. The frequency, magnitude, and duration of the eruptions, the nature of ejected material, the preexisting topography, and the weather conditions interact with such variability that a precise assessment of potential hazard is impossible. However, the risks associated with each type of eruption can be discussed.

There are two major types of volcanoes, shield volcanoes and composite volcanoes. Shield volcanoes are found in the ocean and are typical of those in the Hawaiian Islands. Composite volcanoes are found on the continents and are typical of those in the Cascades. They have very explosive eruptions and often send huge clouds of ash and other volcanic debris far up into the atmosphere. These ash clouds can cover large areas and can even deposit several inches of ash thousands of miles from the volcano. The damage caused by these volcanoes is extensive and widespread. It is this type of volcano that is most likely to affect Montana. Composite or explosive eruptions not only produce large amounts of ash, but also pyroclastic flows (rock and mineral fragments blown out of a volcanic vent during an eruption) and mudflows on and beyond the flanks of the volcano.

The distribution of ash from a violent eruption is a function of the weather, particularly wind direction and velocity, and the duration of the eruption. As the prevailing wind in the mid-latitudes of the northern hemisphere is generally from the west, ash is usually spread eastward from the volcano. Exceptions to this rule do, however, occur. Ash fall, because of its potential widespread distribution, offers some significant volcanic hazards.

C. HISTORICAL OCCURRENCE AND RESPONSE

Cascade Volcanoes

The Cascade Range includes 15 major volcanoes, of which six (Mt. Baker, Mt. Rainier, Mt. Hood, Mt. Shasta, Lassen Peak, and Mt. St. Helens) are considered active, three (Glacier Peak, Mt. Adams, and Newberry Volcano) are considered dormant, and the remaining six (Mt. Garibaldi, Mt. Jefferson, the Three Sisters, and Mt. Mazama [Crater Lake]) are considered extinct (Hyde and others, 1978)[1]. The only threat these volcanoes pose to Montana is that of ash fall. The likely extent of such ash fall can be estimated on the basis of past eruptions.

Glacier Peak

The last major eruption of Glacier Peak (about 11,200 years ago) resulted in the deposit of ash across southwestern Montana. Compacted ash thickness exceed 2½ inches (6 cm) throughout much of this region.

Mount Mazama

The eruption of Mt. Mazama (about 6,600 years ago) was one of the most spectacular eruptions known from the Cascades. About 97,000 cubic yards (75 cubic km) of material was ejected, leaving behind the scenic basin of Crater Lake. The ash blanket from Mt. Mazama covered western Montana, and compacted ash thickness exceeding 15 inches (40 cm) have been noted west of Augusta, MT. Ash thickness between 4 and 8 inches (10-20 cm) have been noted near Great Falls, and the blanket thins eastward (Lemke and others, 1975)[2].

Mount St. Helens

The May, 1980 eruption of Mt. St. Helens resulted in the deposition of up to 3 inches (7 cm) of <u>uncompacted</u> ash in western Montana, tapering to near zero in eastern Montana. It is estimated that this ashfall cost Missoula nearly $6 million in cleanup and lost work time. The statewide cost has been estimated at between $15 and $20 million.

Yellowstone National Park and Vicinity

Another area of volcanic activity that has affected Montana in the past and could pose a serious threat in the future is the Yellowstone Caldera in northwestern Wyoming and northeastern Idaho, just south of the Montana border. A Caldera is a term for a large volcanic crater. The Yellowstone Caldera is 45 miles across at its greatest diameter. The eruptive center has migrated along the axis of the present Snake River Plain over the past 10 million years, with periodic eruptions generating massive pyroclastic flows. The last three eruptions, about 2.1, 1.3, and 0.6 million years ago,

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occurred in the Island Park/Yellowstone region of SW Montana and NW Wyoming. Fortunately for humankind, an eruption comparable in magnitude with those of Yellowstone has not occurred during recorded history.

The Lava Creek A and Mesa Falls ashes were distributed just south of Montana's borders by a consistent wind from the west or northwest. In contrast, the Lava Creek B and Huckleberry Ridge ashes blanketed much of the Central United States, suggesting fluctuating winds during the eruptive cycle. Although the thickness of these blankets have not been accurately determined, it is clear that, under certain wind conditions, much of Montana could receive significant ash from a Yellowstone eruption. The hazard of ash fall from a Yellowstone eruption is thus dependent mainly on the weather at the time of the eruption and on the volume of ash produced. Distribution of Lava Creek B Ash (0.62 my), (from Izett and Wilcox, 1982).[3] Distribution of Huckleberry Ridge Tuff (2.02 my), (from Izett and Wilcox, 1982).[4]

The other primary effects of a volcanic eruption have also been felt within Montana. Initial lava flows were confined to the immediate area of the vent. Later flows affected the headwaters of the Yellowstone River, near Gardiner. In addition, pyroclastic flows (the Huckleberry Ridge Tuff) extended up to 55 miles (90 km) from the vents.

D PREDICTION POTENTIAL FOR RECURRENCE

Given the geological causes for regional volcanism, it is a certainty that further eruptions will occur. The timing of future eruptions, however, is unknown. At present, the only way to assess the probability of eruption of a given volcano is to examine its historical record, and to extrapolate it into the future. This approach assumes that complete record of eruptions is represented in the geologic record, that geologists have correctly interpreted it, and that it will continue similarly into the future. None of these assumptions is entirely valid. The approach, however, suggests that Cascade volcanoes are characterized by periods of dormancy on the order of 10,000 years followed by eruptive cycles with eruptions several hundred years apart. Thus, the volcanoes currently considered active may erupt at any time, and are likely to erupt if the period since their last eruption exceeds several hundred years. Those considered dormant may also erupt at any time, but have no recent activity by which to judge their near future. Because of the lack of interconnection between magma chambers, the eruption of one volcano apparently has no effect on its neighbors.

The three major periods of activity in the Yellowstone system have occurred at intervals of approximately 600,000 years, and the most recent was about that long ago. The evidence available is not sufficient to confirm that calderas such as the Yellowstone erupt at regular intervals, so the amount of time elapsed is not necessarily a valid indicator of imminent activity. There is no doubt, however, that a large body of molten magma exists, probably less than a mile beneath the surface of Yellowstone National Park. The presence of this body has been determined by scientists who note that

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earthquake waves that pass beneath the park behave as they would if passing through a liquid. The only liquid at that location which could absorb those waves is molten rock. The extremely high temperatures of some of the hot springs in the park further suggest the existence of molten rock at shallow depth. A small upward movement could easily cause this magma to erupt. If a major eruption occurred, the explosion would be "comparable to what we might expect if a major nuclear arsenal were to explode all at once, in one place" [5](Alt, 1985).

As with earthquakes, the occurrence of volcanic eruptions is preceded by a number of changes in the geology of the surrounding region. Seismic wave velocities may decrease, implying magma near the surface. Heat flow may increase for the same reason. The frequency of minor earthquakes may increase due to weakening of the heated rocks at depth and to the increase in stresses caused by ascent of magma to the surface. In the case of Mount St. Helens, the depth at which earthquakes occurred decreased as the magma neared the surface (Lipman and Mullineaux, 1981).

All of these warning signs may or may not be present prior to an eruption. It is clear, however, that they will be noticed only if a major program of geophysical monitoring is undertaken.

E. STATE VULNERABILITY TO VOLCANIC ERUPTION

Due to the numerous variables involved, it is difficult to assess the vulnerability of the State of Montana to a volcanic eruption. The primary hazard to which the State may be vulnerable at some future time, is ashfall from a cascade volcano. The effect would depend on the interaction of such variables as source location, frequency, magnitude and duration of eruptions, the nature of the ejected material and the weather conditions. Therefore, the entire state may be considered vulnerable to ashfall to some degree in the event of a volcanic eruption.

Although the probability is minimal, there is the potential for a catastrophic eruption in the vicinity of Yellowstone National Park that would have very serious consequences for Montana and neighboring states. Again, assessing the vulnerability of the State to such an event is impossible due to the numerous variables that must be considered.

F. MITIGATION

The infrequency of volcanic eruptions makes zoning to reduce damage inefficient and unworkable. The violence of such eruptions makes engineering to reduce damage nearly impossible. Even if an eruption were to be predicted, the widespread areas affected make evacuation impracticable outside the immediate vent area. As such, the only useful mitigation tactics throughout most of Montana will be those that take place after the eruption. Those techniques will chiefly combat the effects of ash fall.

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Health

In the case of a major Cascade eruption, the major health hazard involves the inhalation of find glass shards, which may complicate or cause respiratory disorders. The ash may clog both storm and sanitary sewers, causing both inconvenience and health hazards. Observation and appropriate maintenance are effective mitigation.

In the case of a Yellowstone eruption, poisonous gasses may be present. The difficulty of filtering such material may require extensive evacuation of areas otherwise little affected by the eruption. Water supplies exposed to such gasses may be contaminated, with long-term damage to local economies. Replacement or filtration will be an expensive, time-consuming task.

Structures

Most structures in Montana are designed to withstand significant snow loads, so ash loading should not be a major problem. Flat roofs in areas of heavy ash fall, however, may need to be shoveled. Although the density of uncompacted ash is only about 1 gram per cubic centimeter (similar to water), it may increase by 50% when wet (Shirley et al, 1982). The combination of rain and ash fall, therefore, increases the loading by 50%.

Transportation

The silica-rich glass shards of ash are harder than steel, thus excessive wear of machinery can be expected. The best mitigation for this problem is to use oil bath or foam air filters where possible, rather than paper filters (Schuster, 1981). Air, oil, and gas filters should be changed frequently, as should engine oil. Brake drums will also abrade rapidly, and should be cleaned as often as possible.

The removal of ash from highways and airports represented the most widespread problem associated with the 1980 Mt. St. Helens eruption (Schuster, 1981). Plowing was most effective when initiated soon after ash fall began.

Agriculture

A thin ash blanket is likely to be beneficial to crops, as the ash contains trace minerals often leached from agricultural soil. A thicker blanket will have a similar effect, although it will have to be plowed into the ground, with the loss or sacrifice of any existing crop. Extremely thick ash will require re-vegetation over a period of decades.

Climate

Most climatic changes resulting from the addition of particulate matter and aerosols to the atmosphere will be subtle, and will require no mitigation. One possible short-term effect is a change in the rate of snowmelt. A thin ash layer(3 mm; Driedger, 1981) will increase the rate of snowmelt by increasing the amount of solar radiation absorbed at the snow surface. This could slightly increase the possibility of spring flooding, and decrease the storage for summer irrigation. A thick ash blanket will have the opposite effect, acting as insulation at the snow surface.

G. SUMMARY

The volcanic hazard is a very unlikely one, yet with such major potential consequences that it should be considered in emergency planning. The most likely hazard to Montana is that of ash fall from an eruption in the Cascades, with the potential of from 0 to 40 inches of ash blanketing the state. Such eruptions, based on fragmentary records, might occur once a century, on average. Much less likely is the possibility of a catastrophic eruption in the Yellowstone region. Such an eruption might not occur for 100,000, but when it does, it will severely impact much of SW Montana and neighboring portions of Wyoming. Again, the consequences justify the generation of contingency plans.

The best defense against volcanic hazard is monitoring the potential eruptive centers. The U. S. Geological Survey should be encouraged to continue such monitoring.

H. RECOMMENDATIONS

- It is worth repeating that due to the minimal probability and statewide vulnerability that the only useful mitigation tactics will be those that take place after the eruption.

- Inexpensive respiratory filters should be made available to those with respiratory disorders

- When ash is moistened, it becomes both an electrical conductor and a corrosive acid. Sensitive equipment and electrical systems should be cleaned as often as possible to mitigate against short circuits and corrosion.

- Livestock will be subject to the same hazards as humans, and should be provided with filtered air and monitored for respiratory disease as far as possible.

I. REFERENCES

1980 Mt. St. Helens eruption (Schuster, 1981)
The magnitude of the last three Yellowstone eruptions as compared to historic events (from Smith and Braile, 1984).